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SPACE COMPLEX

Aleksandr Nikolayevich Ponomarev

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16. Abstract

Ground stations and computer centers which support space flights work between ground stations and spacecraft during flight are described. Some of the problems relating to space flight and describes certain spacecraft equipment are also presented.

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SPACE COMPLEX

Aleksandr Nikolayevich Ponomarev[1]

At the present time the flight of a spacecraft is supported by a large array of ground facilities. A multistage rocket called a booster is employed to launch a vehicle into orbit. The launch complex consists of the launch pad and its equipment for final assembly and prelaunch check of the booster and the spacecraft. The space vehicle (the spacecraft), the booster, and the mission control center together go to make up the space complex. /38*

The design of a manned space vehicle is determined by the conditions of space flight and by the craft's mission. An artificial atmosphere has to be created and constantly renewed onboard the spacecraft; meteor and radiation shields have to be provided, and loss of heat by radiation from the hull of the ship must be prevented. For all practical purposes the spacecraft moves in a completely unconfined environment and flies by inertia under the effect of gravity of the planets of the Solar System. In order to change its flight path of inertial velocity, it must both expend a certain amount of energy and give up some of its mass.

The geometric form of the spacecraft is determined by the demands of flight in space and in ascent into orbit and return to Earth. The shape of the vehicle has to be symmetrical to lighten the load on the booster and to maintain flight control. On entry into the dense layers of the atmosphere this compact form allows reduction in the surface area which must be protected against high thermal stresses; this conserves the vehicle's mass. The volume of the spacecraft must be as large as possible in relation to its cross-section; this reduces the danger from meteors and radiation and lessens the probability of rupture of the airtightness of the cabin.

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[1] The military press is now putting out a book called "The Years of the Space Era". Its author is the noted aeronautics specialist Colonel General Aleksandr Nikolayevich Ponomarev, Ph.D. (science), and engineer. In a popular science format he discusses the problems confronting scientists of the Soviet Union and of other countries in their quest to conquer space, and he tells how these problems have been resolved. He includes a description of the Soyuz spacecraft and of the Salyut orbital station.

A section of the first chapter is presented above. In this excerpt the author discusses the concepts of a space complex and its basic components.

*Numbers in the margin indicate pagination in the foreign text.

The atmosphere in the cabin of the space vehicle should ideally be the same as on earth at sea level. However, sometimes an atmosphere of pure oxygen at less than sea level pressure, or a mixture of oxygen and an inert gas, is used. Oxygen is consumed efficiently, and thus is purified and continuously recycled. Water vapor and carbon dioxide must be removed, but the oxygen is replenished. The cabin of a space ship is similar in many respects to that of a modern airplane.

The cosmonauts may wear pressurized suits during flight. However, during protracted flights it is very tiring to keep the suits on all the time, so they are used only when they are really needed.

In an emergency the space ship can land in a remote area of the land or sea, and the cosmonaut (like any pilot) has emergency supplies to keep him alive.

The propulsion systems are employed to perform maneuvers. They make either minor changes in the flight path or major changes in the flight speed. In the latter case a large part of the craft's basic inertia has to be overcome by the engines. In any case maneuvers in space are necessary for successful completion of a mission and for the cosmonauts' safe return to Earth.

The simplest propulsion system consists of solid-fuel rockets and can be used in descent from orbit. A more complex propulsion system makes possible maneuvers for docking of spacecraft in orbit and for orbital changes when a space vehicle wants to land on a chosen planet. In this case the craft must have several propulsion systems to permit the landing of part of its crew on the planet and to ensure return of all the crew members to Earth.

Chemical batteries, solar panels, fuel elements, and thermal engines using chemical or nuclear fuel can be used as a source of electrical energy for powering the craft's equipment. The length of the flight and the loads imposed determine the energy source chosen. Usually alternating and direct current are available onboard ship.

The onboard systems of guidance, orientation, and navigation are designed in accordance with the flight missions.

During flight the ship's computer must process a large volume of information and must calculate basic and correction maneuvers so that the ship can travel each section of its flight path with the least possible expenditure of fuel. In the course of each maneuver, the inertial guidance (measurement) system has to coordinate with the onboard computer to direct the vehicle's flight so that the velocity vector is changed in the right way.

Despite the fact that manned spacecraft are equipped with instruments for independent navigation, the ground tracking stations, in coordination with the command centers, help the cosmonauts increase the accuracy of the navigational calculations made onboard.

Manned space ships have several electronic systems which provide the cosmonaut with a two-way communications link to Earth and with telemetric and external trajectory changes. In addition, there electronic systems which facilitate the search for the craft after its return to Earth. For docking in space or landing on another planet, the ship has a radio-operated homing device as a part of its equipment. In case of failure of the ship's navigational system, a constant link is maintained with the ground stations to ensure that the mission is carried out and that the craft returns to Earth.

The interior volume of the space craft. As the size of a space vehicle increases, so does its mass. To increase the useful volume of the ship, the basic stress bearing elements of the structure must be made more durable, and thus heavier. Although the mass of the structure does not increase in proportion to increase in the volume, the mass of the craft is of such importance that designers try to keep the space vehicle as small as possible in volume. The various systems inside the ship must also be installed very compactly to minimize the space they take up. The position of the ship's center of gravity must also be very carefully maintained, and this requirement causes additional problems in weight distribution. In addition, certain pieces of equipment can be installed only in specific places. Obviously the problem of the distribution of the instruments can be made easier if the dimensions of the craft are increased or if the size of the equipment is decreased.

It is also useful to provide some reserve space in the interior of the craft if its mass allows it. /39

Building the ship with a somewhat enlarged volume not only facilitates the design, manufacture, trial, operation, and maintenance of the craft, but also enhances its reliability and increases the chance that the craft will be able to carry out other missions. Models are used in assembly and placement of the equipment. This permits exploration of various equipment placement possibilities by the trial and error method.

Reliability. Manned spacecraft must perform dependable, since they carry a cosmonaut into a little known environment into which it is difficult to penetrate for rescue operations.

For this reason reliability is a decisive requirement in the planning and designing of a space vehicle. Each engineering decision can be made only when evaluation of its effect on the spacecraft's reliability no longer raises any doubts. The technology of its construction, the materials, the quality control process, the transportation methods, the final check of the whole craft, and the other areas of development of a spacecraft must be painstakingly worked out, and all the initial conditions must meet the requirement of absolute reliability.

Let us consider some of the ways in which system reliability can be increased:

1. Installation of backup units for all elements and systems which can fail, or the installation of backup systems of different design which can take over the functions of the primary systems;

2. Simplification or strengthening of systems, the goal of which is to reduce the number of parts which can fail, or to eliminate them altogether;

3. The use of thoroughly tested systems the best suited to their function.

It is possible to achieve considerable improvement in the performance of manned spacecraft if equipment which has served its purpose is jettisoned during flight.

The jettisoning of the rescue system engine cuts the losses caused by its weight. It is also sensible to discard burnt out braking engines before entering the denser atmosphere on return to Earth and to retain only the reentry vehicle. Such jettisoning reduces the mass of the returning capsule and permits corresponding reduction in the mass of the vehicle as a whole and of its heat shield.

The Soyuz and Apollo space vehicles discard considerable mass before reentry into the atmosphere and its dense layers. In particular, they jettison parts of the orientation and maneuvering systems, as well as the braking mechanism and the instrument and orbital compartments. All this considerably increases the flexibility of design and indirectly ensures a great saving of weight. At the same time, it improves the design of the craft and enhances its reliability.

Distribution of the equipment of the space ship in large isolated compartments is a universally adopted means of gaining an advantage in separation of the stages and in jettisoning equipment no longer needed. Specifically, the Apollo space ship for flight to the moon has a crew compartment, one for equipment, and lunar vehicle compartment. During reentry into the atmosphere and during most of the flight the astronauts work and stay in the crew compartment.

The boosters. Multistage rockets are used to achieve a large part of the high velocity necessary at the end of the active segment. The losses of velocity due to gravitational forces and drag being disregarded, it is calculated that the final velocity of a single-stage rocket will equal the natural logarithm of the mass ratio (the ratio of the liftoff mass to the mass of the rocket at time of engine burnout), multiplied by the specific thrust and by the gravitational constant. Thus the mass ratio is a quantity determining the flight velocity. In practice the mass ratio is limited by engineering considerations. Calculations show that the maximum possible velocity of a single-stage rocket is limited -- it is about 6000 m/sec without the use of a high-performance fuel, which can raise the speed by about a third.

To ensure high fuel performance individual parts of the multistage rocket are chosen so that each stage increases the velocity by 4500-4600 m/sec.

It must nevertheless be noted that to obtain such an increase in velocity during flight at low speeds considerably more fuel is consumed than at high speeds. The reason for this difference is that at low velocity the craft has a high mass and consumes more fuel just to attain the same speed increment. In reality if all stages had propulsion systems of equal specific thrust, then for an equal expenditure of mass there would be an equal increase in speed.

The launch complex, in addition to the launching pad on which the launch platform, the maintenance gantry, and the launch control blockhouse are located, includes special buildings designed for the final clearance check of the systems and of the weight and balance measurements, and also for other final preparations. There are also assembly shops where the individual booster and rocket stages are experimentally fitted with the space capsule.

The command center. The flight control center, a part of the command center, is the main control point. The center personnel have all data about the flight at their fingertips. They know the trajectory of the flight and the vehicle's position at every point. The center's computers predict the space vehicle's flight path and dictate any necessary corrective maneuvers. Special operators check the work of the ship's own basic systems. Medical equipment monitors the physical condition of the cosmonauts. Practically all information pertaining to the flight is collected and converted into readily usable form, after which it is passed to the operators who can assist the cosmonauts at any moment.

A net of tracking stations is connected with the command computer center. The stations are so situated that during the course of the whole flight the spacecraft is always within the radio horizon of one or more of them. The stations are equipped with tracking radar and have two-way communications with the vehicle; they usually act as a relay link between the craft and the control center. Some of these stations have equipment which enables them to take over control of the flight at critical times so as not to be completely dependent on ground links with the command computer center.

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